Chapter 4
Reference Systems and Transformations

4-1. General

The discipline of surveying consists of locating points of interest on the surface of the earth. Points of interest are defined by spherical or planar coordinate values that are referenced to a defined mathematical figure. In surveying, this mathematical figure may be an equipotential surface, ellipsoid of revolution, or a plane.

a. Geoid. The geoid is an equipotential surface where the plumb line is perpendicular to each point on its surface. The geoid is considered a mean sea level (MSL) surface extended continuously through the continents. The geoidal surface is irregular due to mass excesses and deficiencies within the earth (Figure 4-1). The geoidal surface is the reference system for orthometric heights and astronomic coordinates.

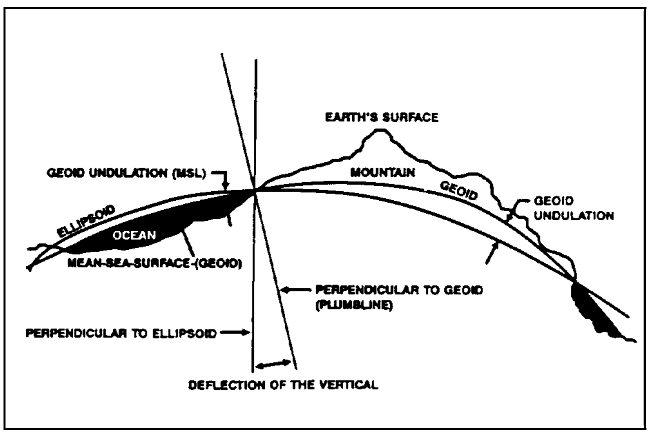


Figure 4-1. The relationship between the ellipsoid, geoid, and the physical surface of the Earth

b. Ellipsoid. An ellipsoid of revolution is a mathematical figure that "best" approximates the geoid (Figure 4-1). The ellipsoid of revolution is developed by rotating an ellipse about its semi-minor axis (b) and is symmetric to the equator.

Ellipsoid of revolution:

$$X^2/a^2 + Y^2/a^2 + Z^2/b^2 = 1$$

where

X,Y,Z = Cartesian coordinates

a = semi-major axis

b = semi-minor axis

The ellipsoid of revolution provides a defined mathematical surface to calculate geodetic distances, azimuths, and coordinates. Some adjustment, transformation, and GPS postprocessing software packages require the user to input the size and shape of the reference ellipsoid. The semi-major (a) and semi-minor (b) axes are used to determine the ellipsoid size (Figure 4-2). The ellipsoid shape can also be defined by the flattening (f), reciprocal of flattening (f^{-1}), eccentricity, and second eccentricity (e').

Flattening: $f = (a-b)/a$

Reciprocal of flattening: $f^{-1} = 1/f$

Eccentricity: $e = (a^2 - b^2)^{0.5}/a$ *or*
$e = (2f - f^2)^{0.5}$

Second eccentricity: $e' = (a^2 - b^2)^{0.5}/b$

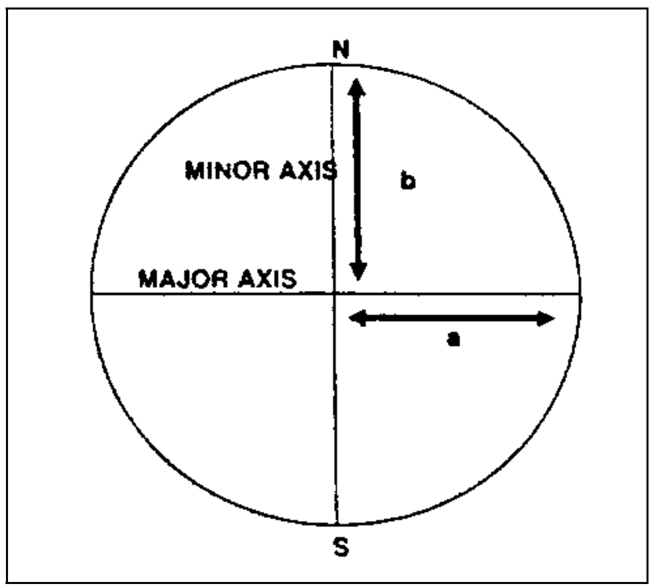


Figure 4-2. Ellipse

Table 4-1 contains the ellipsoid parameters for the Clarke 1866, Geodetic Reference System 1980 (GRS 80), and the World Geodetic System 1984 (WGS 84) reference ellipsoids. The Clarke 1866 and GRS 80 are the mathematical surfaces utilized by the North American Datum 1927

Table 4-1
Ellipsoidal Parameters

Datum	
NAD 27	
Ellipsoid	Clark 1866
Semi-major axis (a)	6,378,206.4 m
Flattening (1/f)	294.9786982
NAD 83	
Ellipsoid	GRS 80
Semi-major axis (a)	6,378,137.0 m
Flattening (1/f)	298.257222101
WGS 84	
Ellipsoid	WGS 84
Semi-major axis (a)	6,378,137.0 m
Flattening (1/f)	298.257223563

(NAD 27) and the North American Datum 1983 (NAD 83). The WGS 84 is the reference system utilized by the GPS. The WGS 84 and NAD 83 are considered synonymous in the continental United States. However, in some locations, positional variations of several meters may occur between the NAD 83 and WGS 84.

c. Cartesian coordinates (X, Y, Z). Cartesian coordinates are considered a true three-dimensional coordinate system. They can be referenced to a regional ellipsoid (Clarke 1866), a global ellipsoid (WGS 84), a plane, or a single point. Cartesian coordinates are termed geocentric if they are related to a global ellipsoid which has its coordinate origin at the mass center of the earth. However, Cartesian coordinates are seldom utilized in engineering and cadastral surveys.

d. Geodetic coordinates. Geodetic coordinates consist of latitude (ϕ), longitude (λ), and ellipsoid height (h). Geodetic latitude, longitude, and ellipsoid height define the position on the surface of the earth with respect to the reference ellipsoid (Figure 4-3).

(1) Geodetic latitude (ϕ). The geodetic latitude of a point is the angle between the equatorial plane and the normal through the point on the ellipsoid (Figure 4-3). Geodetic latitude is positive north of the equator and negative south of the equator.

(2) Geodetic longitude (λ). The geodetic longitude is the angle measured in the equatorial plane from the prime meridian (Greenwich meridian) to the defined point (Figure 4-3). Longitude is commonly measured eastward from the Greenwich meridian (0°-360°). In the continental United States, longitudes are expressed westerly. To convert easterly to westerly referenced longitudes, the easterly longitude must be subtracted from three hundred and sixty degrees (360°).

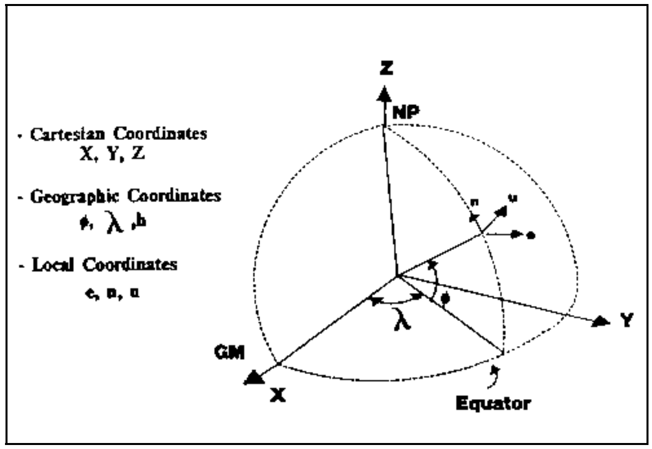


Figure 4-3. Coordinate reference frames

East-west longitude conversion:

λ = 282 52 36.345 E

λ = 360 - 282 52 36.345 E

λ = 77 07 23.655 W

(3) Ellipsoid height (h). The ellipsoid height above the reference ellipsoid is the distance measured along the ellipsoidal normal to the point in question. The ellipsoid height is positive if the reference ellipsoid is below the topographic surface and negative if the ellipsoid is above the topographic surface. The ellipsoid height is not utilized in engineering and cadastral surveys.

(4) Geoid separation (N). The geoid separation is the distance between the normal to the reference ellipsoid and the geoid. The geoid separation is positive if the geoid is above the ellipsoid and negative if the geoid is below the ellipsoid.

(5) Orthometric height (H). The orthometric height is the vertical distance of a point above or below the geoid. In the United States, elevations are commonly referenced to MSL which approximates the geoidal surface. Orthometric (MSL) heights are utilized in engineering, construction, and topographic surveys.

e. Datum. A datum is a numerical or geometrical reference system. Horizontal and vertical datums are commonly used in surveying and mapping. Horizontal and vertical datums are further subdivided as project and geodetic.

(1) Horizontal datum. A horizontal datum is defined by the geometric figure utilized (plane, ellipsoid, sphere) in coordinate, distance, and directional calculations; initial reference point (origin); and a defined azimuth or bearing from the initial point.

(a) Geodetic datum. Five parameters are required to define a geodetic datum: the semi-major axis (a) and flattening (f) define the size and shape of the reference ellipsoid; the latitude and longitude of an initial point; and a defined azimuth (α) from the initial point. The NAD 27 and NAD 83 are examples of geodetic datums. For example, the NAD 27 utilizes the Clarke 1866 ellipsoid. The initial point for the NAD 27 is at Meades Ranch, Kansas, and a defined azimuth extends from Meades Ranch to Station Waldo.

(b) Project. A project datum is relative to local control and may not be directly referenced to a geodetic datum. Project datums are the most common reference system utilized by the Corps of Engineers.

(c) The adjusted horizontal datums typically used are the NAD 27 and NAD 83. The FGCS, of which USACE is a member, has adopted the NAD 83 as the horizontal datum for surveying and mapping activities performed or financed by the Federal Government. To the extent practicable, legally allowable, and feasible, the USACE should use NAD 83 in its surveying and mapping activities. Transformations between NAD 27 and NAD 83 are done using the *CORPS Con*vert (i.e., CORPSCON) software package or other *N*orth *A*merican *D*atum *C*onversion (i.e., NADCON) based program whenever a survey or resurvey with new control or a readjustment of the original survey observations cannot be done. (See Appendix D.)

(d) The NAD 27 is based on an adjustment of the Clarke 1866 reference ellipsoid. The origin and orientation of NAD 27 is defined relative to a fixed triangulation station in Kansas (i.e., Meades Ranch). Azimuth orientation for NAD 27 is South. The original network adjustment for NAD 27 included approximately 25,000 stations. The best fitting area for the resultant adjustment is North America. The longitude origin for NAD 27 is the Greenwich Meridian. The reference units are U.S. Survey Feet and the coordinate values are defined in terms of x and y.

(e) The NAD 83 is defined relative to the Geodetic Reference System of 1980 (GRS 80). GRS 80 is an ellipsoid model based on the mass center of the earth. Azimuth orientation for NAD 83 is North. The original network adjustment for NAD 83 included approximately 250,000 stations. The best fitting area for the resultant adjustment is worldwide. The longitude origin for NAD 83 is the Greenwich Meridian. The reference units are meters and the coordinate values are defined in terms of easting and northing.

(2) Vertical datum.

(a) A vertical datum is a reference system for elevations. Vertical datums are most commonly referenced to MSL, mean low water (MLW), mean low low water (MLLW), or mean high water (MHW). MSL elevations are utilized for construction, photogrammetric, geodetic, and topographic surveys. MLW elevations are utilized in dredging projects. MHW elevations are utilized in construction projects involving bridges and tunnels.

(b) The vertical reference system most often used in the past was the NGVD 29. The NAVD 88 is to be used for all future work. Transformations between NGVD 29 and NAVD 88 will be done using the *Vert*ical *Con*version (i.e., VERTCON) software whenever a survey or resurvey with new control or a readjustment of the original survey observations cannot be done.

4-2. The SPCS

The SPCS was developed by the NGS to provide a planar representation of the earth's surface. To properly relate spherical coordinates (ϕ,λ) to a planar system (northings and eastings), a developable surface must be constructed. A developable surface is defined as a surface that can be expanded without stretching or tearing. The two most common developable surfaces or map projections used in surveying and mapping are the cone and cylinder (Figure 4-4). The projection of choice is dependent on the north-south or east-west areal extent of the region. Areas with limited east-west dimensions and indefinite north-south extent utilize the Transverse Mercator (TM) projection. Areas with limited north-south dimensions and indefinite east-west extent utilize the Lambert projection. The SPCS was designed to minimize the distortion at a point to approximately one-part in ten thousand (1:10,000). To achieve this criterion, the SPCS has been divided into zones that have a maximum width or height of approximately one-hundred and fifty eight statute miles (158 miles). To minimize distortion, each state may have several zones or may employ both the Lambert and TM projections. For example, Florida consists of one Lambert zone that encompasses the panhandle region and two TM zones that cover the remainder of the state. The TM and Lambert projections are conformal. A conformal

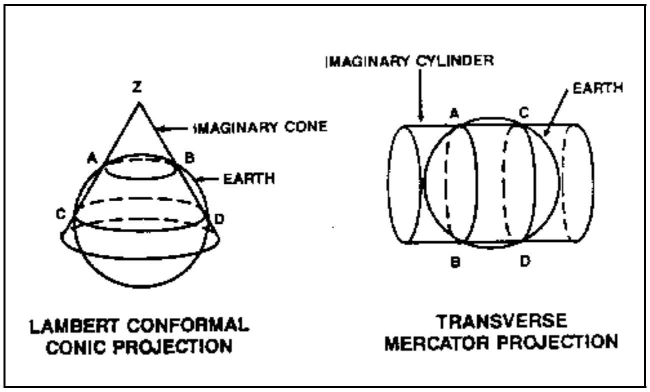


Figure 4-4. Common map projections

projection preserves angular relationships. Angles measured on the ellipsoid are equal to angles measured on a conformal projection. To calculate TM or Lambert projection state plane coordinates, the user must identify the datum to which the geodetic coordinates are referenced.

a. The TM. The TM projection utilizes a cylindrical surface. The cylinder is perpendicular to the rotation axis of the ellipsoid and intersects the ellipsoid along two ellipses equidistant from the central meridian (Figure 4-5). Distortions in the TM projection increase in the east-west direction; therefore, the TM projection is utilized in states with north-south extent. The TM scale factor is unity where the cylinder intersects the ellipsoid. The scale factor is less than one within the lines of intersection and greater than one outside the lines of intersection (Figure 4-5). The scale factor is the ratio of arc length on the projection to arc length on the ellipsoid. To compute the state plane coordinates of a point, the latitude and longitude of the point and the projection constants for that zone or state must be known.

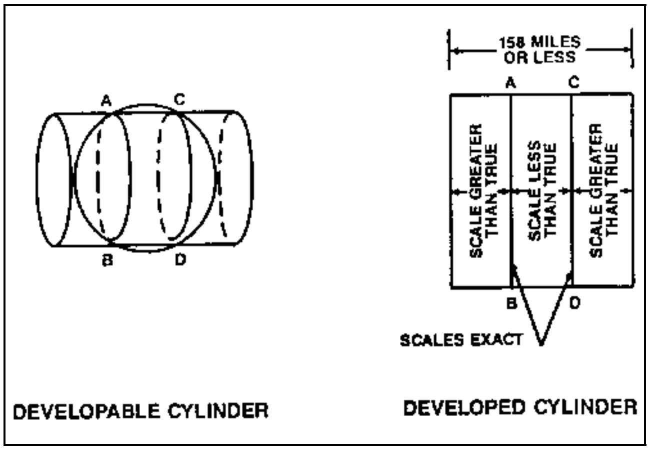


Figure 4-5. TM projection

b. Lambert conformal conic. The Lambert projection utilizes a cone that is coincident with the rotational axis of the ellipsoid and intersects the ellipsoid along two standard parallels (Figure 4-6). The scale factor is equal to unity at the standard parallels and is less than one inside and greater than one outside the standard parallels. The scale factor remains constant along the parallel; therefore, the Lambert projection is ideal for states with indefinite east-west extent.

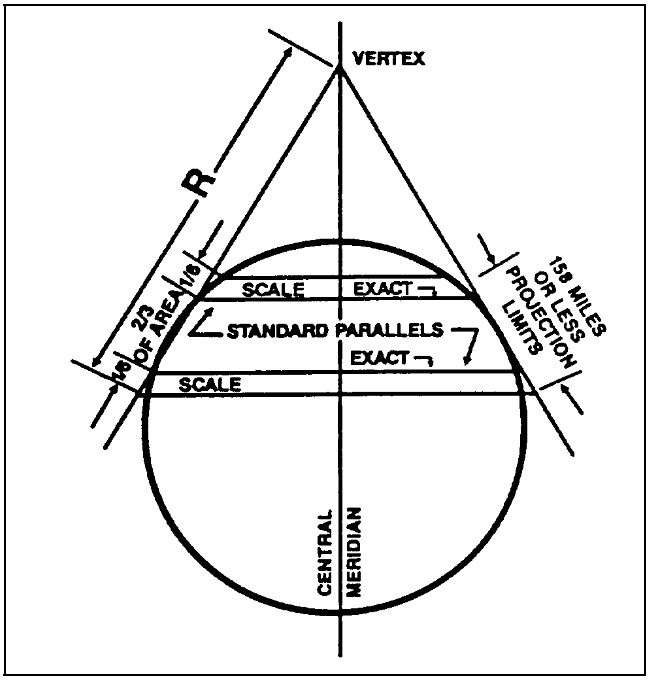


Figure 4-6. Lambert projection

c. Grid distances. Grid distances are computed by multiplying the horizontal distance measured in the field by the combination or grid factor. The combination factor consists of the sea level and scale factor. The sea level factor is computed by dividing the mean radius of the earth by the sum of the mean earth radius and the average elevation between the points. The mean radius of the earth is approximately twenty million nine-hundred and six thousand feet (20,906,000 ft or 68,589,101.667 m). The sea level distance is obtained by multiplying the sea level factor by the measured distance.

Sea level factor:

$$SL = R/(R + H)$$

where

SL = sea level factor

R = mean earth radius

H = average elevation

Example

Measured distance = 2,623.000 feet

Average elevation (H) = 300 feet

Sea level (SL) factor = 0.999985650259

Reduced distance = 2,622.962 feet

The scale factor is a function of latitude and can be interpolated from tables published from the National Oceanic and Atmospheric Administration (NOAA).

d. Units. State plane coordinates can be expressed in both feet and meters. State plane coordinates defined on the NAD 27 are published in feet. State plane coordinates defined on the NAD 83 are published in meters; however, state and Federal agencies can request the NGS to provide coordinates in feet. If NAD 83 state plane coordinates are defined in meters and the user intends to convert those values to feet, the proper meter-foot conversion factor must be utilized. Some states utilize the International Foot rather than the U.S. Survey Foot in the conversion of feet to meters.

International Foot:

1 International Foot = 0.3048 meter (Exact)

U.S. Survey Foot:

1 U.S. Survey Foot = 1200/3937 meter (Exact)

e. NAD 83 versus NAD 27 state plane coordinates. The major difference between NAD 83 and NAD 27 state plane coordinates is that NAD 83 state plane coordinates are published in meters. Also, in the establishment of the NAD 83 SPCS, some zones that were present in the NAD 27 system were eliminated. Future USACE projects should adopt the NAD 83 SPCS.

4-3. Universal Transverse Mercator (UTM)

UTM coordinates are used in surveying and mapping when the size of the project extends through several state plane zones or projections. UTM coordinates are also utilized by the U.S. Army, Air Force, and Navy for mapping, charting, and geodetic applications. The UTM projection differs from the TM projection in the scale at the central meridian, origin, and unit representation. The scale at the central meridian of the UTM projection is 0.9996. In the northern hemisphere, the northing coordinate has an origin of zero at the equator. In the southern hemisphere, the southing coordinate has an origin of ten million meters (10,000,000 m). The easting coordinate has an origin of five-hundred thousand meters (500,000 m) at the central meridian. The UTM system is divided into sixty (60) longitudinal zones. Each zone is six (6) degrees in width extending three (3) degrees on each side of the central meridian. The UTM system is applicable between latitudes eighty-four degrees north (84 N) to eighty degrees south (80 S). To compute the UTM coordinates of a point, the TM coordinates must be determined. The UTM northing or southing (N_{UTM}, S_{UTM}) coordinates are computed by multiplying the scale factor (0.9996) at the central meridian by the TM northing or southing (N_{TM}, S_{TM}) coordinate values. In the southern hemisphere, a ten-million-meter (10,000,000-m) offset must be added to account for the origin. The UTM eastings (E_{UTM}) are derived by multiplying the TM eastings (E_{TM}) by the scale factor of the central meridian (0.9996) and adding a five-hundred-thousand-meter (500,000-m) offset to account for the origin. UTM coordinates are always expressed in meters.

UTM northings, southings, and eastings

$$N_{UTM} = (0.9996)N_{TM} \text{ (Northern Hemisphere)}$$

$$S_{UTM} = (0.9996)S_{TM} + 10{,}000{,}000 \text{ m (Southern Hemisphere)}$$

$$E_{UTM} = (0.9996)E_{TM} + 500{,}000 \text{ m}$$

The UTM zone (Z) can be calculated by knowing the geodetic longitude of the point. In the continental United States the UTM zones range from ten (10) to nineteen (19). If the value **Z** is a decimal quantity, the zone must be incremented by one. In the example below **Z** is a decimal quantity; therefore, the zone equals seventeen (17) plus one (1).

Zone

$$Z = (180 + \lambda)/6 \text{ (Easterly Longitude)}$$

$$Z = (180 - \lambda)/6 \text{ (Westerly Longitude)}$$

where Z = UTM Zone Number

Example UTM zone calculation

λ = 077° 08' 44.3456" W

Z = 17.14239

Z = 17 + 1

Z = 18

4-4. Geocentric Coordinate Systems

a. World Geodetic System of 1984 (WGS 84). The geocentric reference system used most often is the WGS 84. This is because WGS 84 is the reference ellipsoid for GPS. For most applications, the three-dimensional (3-D) geocentric coordinates of WGS 84 are converted into their equivalent two-dimensional (2-D) horizontal and vertical components and then used. For example, the geocentric coordinates are most often converted to 2-D NAD 83 SPCS horizontal coordinates and ellipsoid elevation values.

b. Ellipsoid coordinate system definition. Once the reference ellipsoid is defined, a 3-D (i.e., x, y, and z axis) Cartesian coordinate system also can be defined relative to the ellipsoid definition. Subsequent determination of a point relative to the reference ellipsoid and associated Cartesian coordinate system is made based on the difference in x, y, and z (i.e., Δx, Δy, and Δz) between the x, y, and z of the point and the references ellipsoid/Cartesian coordinate axes.

4-5. Geocentric Conversions

The primary use of geocentric coordinates is in conjunction with the use of GPS for the densification of military construction and civil works project control. Horizontal and vertical densification are handled as separate issues, therefore necessitating the conversion of the 3-D geocentric coordinates to 2-D horizontal components (i.e., x and y or latitude and longitude) and an elevation on a particular datum. Conversion of geocentric coordinates in this manner permits their use, for practical engineering purposes, directly on any local user datum. For example, GPS derived WGS 84 baselines in a network (i.e., geocentric coordinates) can be directly used on an NAD 27, NAD 83, or even a local project datum. Minor variation between these datums will be minimal when the GPS data used to formulate the baselines are used to adjust the fit between the local datum stations. Such assumptions are good for a localized project but may not be as valid when high-order NGRS network densification work is being performed.

a. Geodetic to Cartesian coordinate conversion. Given geodetic coordinates on NAD 83 (in ϕ, λ, H) or NAD 27, the geocentric Cartesian coordinates (X, Y, and Z) on the WGS 84, GRS 80, or Clarke 1866 ellipsoid can be converted directly by formulas as related in EM 1110-1-1003.

b. Cartesian to geodetic coordinate conversion. In the reverse case, given GRS 80 X, Y, Z coordinates, the conversion to NAD 83 geodetic coordinates (ϕ, λ, H) can be performed using a noniterative method (Soler and Hothem 1988) that is detailed in EM 1110-1-1003.

c. OCONUS Cartesian to geodetic coordinate conversion. Transformations between other OCONUS datums may be performed by changing the ellipsoidal parameters (i.e., *a*, *b*, and *f*) shown in EM 1110-1-1003 to the OCONUS datum's reference ellipsoid.

d. Example geographic to geocentric coordinate transformation. An example of a geographic to geocentric transformation can be found in EM 1110-1-1003.

e. Example geocentric to geographic transformation. An example of a geocentric to geographic transformation can be found in EM 1110-1-1003.

4-6. Horizontal Transformations NAD 27 to NAD 83

a. Conversion techniques. Any USACE survey control which was in the NGS database should have been converted to NAD 83 with corresponding results published by NGS. However, most USACE survey control, although referenced to NAD 27, was not in the NGS database and was not included in the NGS readjustment and redefinition of the national geodetic network. Therefore, the USACE will have to convert this control to NAD 83 by some mathematical adjustment or transformation process. All conversion methods are dependent on the existence of nearby survey controls that are, or can be, referenced to both the NGS NAD 83 database and the USACE survey control requiring conversion. These are referred to as common stations from which unknown or intermediate points are best fitted. The process is analogous to that of a simple traverse adjustment; e.g., if the fixed control points are changed, then a recomputation of the intermediate traverse stations causes a differential shift at each point proportionate to the overall change in the fixed coordinates. Although a variety of methods exist to perform these conversions, only the three that are considered applicable to USACE projects are discussed below.

(1) Survey or resurvey of projects using NAD 83 control. A new survey using NGS published NAD 83 control could be performed over an entire project. This could be either a newly authorized project or one undergoing major renovation or maintenance. A resurvey of an existing project must tie in all monumented points and may be performed using any conventional survey procedure. Although this is not a datum transformation technique, it accomplishes the same thing. A resurvey of an existing project would not normally be economically justified unless major renovation work is being performed or the existing NAD 27 control is of low density or accuracy. A resurvey of an existing project should not be performed solely to transform the project to NAD 83. One of the other methods described below should suffice. One disadvantage of this procedure is that other users of USACE survey data may also convert these data to NAD 83 using a mathematical transformation resulting in different coordinate values for the same survey points. If this method is employed, actions may have to be taken to notify other users of the USACE NAD 83 coordinates.

(2) Readjustment of original survey observations. If the original project control survey was connected to common NGS stations, the survey may be readjusted using NAD 83 coordinates instead of the NAD 27 coordinates originally used. This method involves locating the original field angular, distance, and azimuth observations, and completely readjusting the survey using a recognized adjustment method, such as a rigorous least-squares or other equally adequate semi-rigorous method (including traditional traverse adjustment methods). The original Corps survey scheme (e.g., traverse, triangulation, trilateration, etc.) must have been rigidly connected to the National Geodetic Control Network (i.e., published coordinates on both NAD 27 and NAD 83), which allows the readjustment process to be performed using only the published NAD 83 control as fixed. This procedure is extremely labor intensive and would be justified only on selected projects. Another disadvantage of this procedure is that other users of USACE survey data may also convert these data to NAD 83 using a mathematical transformation resulting in different coordinate values for the same survey points. It is, however, theoretically superior to the mathematical transformation methods described below. If this method is employed, actions may have to be taken to notify other users of the USACE NAD 83 coordinates.

(3) Mathematical transformations. Since neither of the above methods can be economically justified on many USACE projects, mathematical techniques for transforming project control data to NAD 83 have been developed. These methods yield results which are normally better than ± 1 foot of the actual values and errors are typically consistent within a project area. Therefore, they are considered approximate. However, this will probably meet most USACE needs. They should be used with caution when real property demarcation points are involved. When mathematical transformations are employed they should be adequately noted so that users will be aware of the conversion method and accuracy of the resulting coordinates.

(a) A 3-D coordinate transformation process from one geodetic reference system to another can generally be represented as a simple three-step process:

(1) Convert elliptical (geodetic or geographical) angular coordinate system to a 3-D rectangular (Cartesian) coordinate system.

(2) Translate and reorient the origin from the old ellipsoid/datum to the new ellipsoid/datum using known translation and orientation values.

(3) Convert the new Cartesian system to its geodetic ellipsoid coordinate reference system.

Performing the second step is not straightforward since the method of defining the datum origin and axis orientation parameters differs significantly between NAD 27 and NAD 83. Thus, a simple 3-D coordinate relationship does not exist between the two systems. As a result, local scale distortions exist between NAD 27 and NAD 83 and this distortion is known only at NGS published points common to both datums. Such NGS control which was originally published on NAD 27 and readjusted as part of the 1983 NAD redefinition are termed common points.

(b) A USACE survey control point will typically fall between these common points, and the distortion at this point due to the NAD 83 readjustment can only be estimated. Since coordinates are known for common points which were included in both the NAD 27 and NAD 83 adjustments, datum differences or shifts at these common points provide the necessary mathematical model to transform points which were not common to both datums. Such a coordinate transformation process is usually performed by a so-called rigorous mathematical minimization or regression technique. This is typically accomplished by some form of a least squares adjustment whereby the point to be transformed is best fitted between the surrounding common points. A rigorous transformation from NAD 27 to NAD 83 does account and compensate for not only the ellipsoidal orientation differences but also the local readjustment changes in the reference network. Any point which has been converted by such a transformation method should be considered as having approximate NAD 83 coordinates. This is because these coordinates were not computed using original survey observations.

b. Performing mathematical transformations. Numerous mathematical techniques have been developed to convert coordinates from NAD 27 to NAD 83. These include a variety of multiple parameter transformation equations and multiple regression transformation equations. Each technique has advantages and disadvantages in terms of accuracy, consistency, and complexity of the process.

(1) LEFTI. One of these was the computer program LEFTI, developed by NGS and distributed within USACE by the U.S. Army Topographic Engineering Center (TEC) in 1987 within the computer program DATATRAN. The results from LEFTI are dependent upon the selection of a set of points which are common to both NAD 27 and NAD 83. Selecting different common points yields different NAD 83 coordinates of the other points being converted. As various conversions are performed with LEFTI, different coordinates will be computed for the same point. Although these differences are small, they create inconsistency in survey data which could lead to intolerable situations for many applications.

(2) NADCON/CORPSCON. To eliminate these inconsistencies, NGS developed the transformation program NADCON which does not require selection of common points and yields consistent results. This technique is based on a bi-harmonic equation classically used to model plate deflections. NADCON has been reconfigured by TEC into a more comprehensive program called CORPSCON, which also converts between SPCS 27, SPCS 83, UTM 27, and UTM 83; thus eliminating several steps in the total process. CORPSCON will be the standard conversion method for USACE, replacing the previously used LEFTI. Technical documentation and operating instructions for CORPSCON are contained in Appendix D.

c. Distortion of dimensions. In addition to changing all coordinates on a project, the conversion process could slightly modify project dimensions. Localized coordinate changes created by the 1983 readjustment could result in very slight distortions of project dimensions and alignment data. This is due to the varying amount of datum shift from point to point. This variation could be significant over small distances typically encountered on USACE projects. For this reason, care must be taken in the use of mathematical transformations to convert existing control to NAD 83, whether it be fixed monumented points or project alignment data, e.g., PIs, PTs, and all other similar computed or nonoccupied points. As stated earlier, this variable shift is due to both the readjustment and redefinition of the NAD 83 reference datum. In addition, the various SPCS 83 grid references were redefined with origins deliberately changed by large amounts to avoid confusion with the older SPCS 27. When transformed NAD 83 geographic coordinates are subsequently converted to redefined SPCS 83 grid coordinates, the total magnitude of the coordinate shift between SPCS 27 and SPCS 83 contains both the geographic datum shift (due to redefinition and readjustment) and the local grid redefinition shift.

(1) Shift gradients. Since the overall datum shift varies from point to point throughout North America, the amount of datum shift across a local project is not constant. The variation can be as much as 0.1 foot per mile. Some typical coordinate shift variations that can be expected over a 10,000-foot section of a project are shown below:

Project Area	SPCS Reference	per 10,000 feet
Baltimore, MD	1900	0.16 ft
Los Angeles, CA	0405	0.15 ft
Mississippi Gulf Coast	2301	0.08 ft
Mississippi River (IL)	1202	0.12 ft
New Orleans, LA	1702	0.22 ft
Norfolk, VA	4502	0.08 ft
San Francisco, CA	0402	0.12 ft
Savannah, GA	1001	0.12 ft
Seattle, WA	4601	0.10 ft

(2) Example. Such local scale changes will cause project alignment data to distort by unequal amounts. Thus, a 10,000.00-foot tangent on 1927 NAD project coordinates could end up as 9,999.91 feet after a mathematical transformation of the PI stations to NAD 83 coordinates. Although such variances may not be physically significant from a construction standpoint, the potential for such numerical anomalies must be recognized. Therefore, in addition to significantly changing all absolute coordinates on a project, the datum transformation process will slightly modify the project's design dimensions and/or construction orientation and scale. On a navigation project, for example, an 800.00-foot-wide channel could

vary from 799.98 to 800.04 feet along its reach. The grid azimuth between the PIs will also change. If the local SPCS 83 grid was modified, then even larger dimension changes can result.

(3) Corrections. Correcting this may require recomputation of coordinates after conversion to ensure that original project dimensions and alignment data remain intact. This is particularly important for property and boundary surveys. Alternatively, a fixed shift may be applied to all data points over a limited area. Determining the maximum area over which such a fixed shift can be applied is important.

(4) Computing fixed conversion factors. CORPSCON may be employed to compute a conversion factor to within ±1 foot. This conversion could be held fixed and applied to all coordinates over a given sector of a project or an entire project. Typically, this fixed conversion would be computed at the center of a sheet or at the center of a project and the conversions in X and Y from NAD 27 to NAD 83 and from SPCS 27 to SPCS 83 indicated by notes on the sheets or data sets. Since the conversion is not constant over a given area, the fixed conversion amounts must be explained in a note. The magnitude of the conversion factor gradient across a sheet is a function of location and the drawing scale. Whether the magnitude of the gradient is significant depends on the nature of the project. A 0.5-foot variation on an offshore navigation project may be acceptable for converting depth-sounding locations, whereas a 0.1-foot gradient may be intolerable for construction layout on an installation. In any event, the magnitude of this gradient should be computed by CORPSCON at each end (or corners) of a sheet or project. If the conversion factor variation exceeds the allowable tolerances, then a fixed conversion factor should not be used. Examples of two fixed conversion factors follow:

(a) Let's assume we have a 1" = 40' scale site plan map on existing SPCS 27 (VA South Zone 4502). Using CORPSCON, convert existing SPCS 27 coordinates at the sheet center and corners to SPCS 83 (U.S. Survey Foot), and compare SPCS 83 and 27 differences.

	SPCS 83	SPCS 27	SPCS 83 - SPCS 27
Center	N 3,527,095.554	Y 246,200.000	dY = 3,280,895.554
of sheet	E 11,921,022.711	X 2,438,025.000	dX = 9,482,997.711
NW	N 3,527,595.553	Y 246,700.000	dY = 3,280,895.553
corner	E 11,920,522.693	X 2,437,525.000	dX = 9,482,997.693
NE	N 3,527,595.556	Y 246,700.000	dY = 3,280,895.556
corner	E 11,921,522.691	X 2,438,525.000	dX = 9,482,997.691
SE	N 3,526,595.535	Y 245,700.000	dY = 3,280,895.535
corner	E 11,921,522.702	X 2,438,525.000	dX = 9,482,997.702
SW	N 3,526,595.535	Y 245,700.000	dY = 3,280,895.535
corner	E 11,920,522.704	X 2,437,525.000	dX = 9,482,997.704

Since coordinate differences do not exceed 0.03 foot in either the X or Y direction, the computed SPCS 83-27 coordinate differences at the center of the sheet may be used as a fixed conversion factor to be applied to all existing SPCS 27 coordinates on this drawing.

(b) Assuming a 1" = 1,000' base map is prepared of the same general area, a standard drawing will cover some 30,000 feet in an east-west direction. Computing SPCS 83-27 differences along this alignment yields the following:

	SPCS 83	SPCS 27	SPCS 83 - SPCS 27
West	N 3,527,095.554	Y 246,200.000	dY = 3,280,895.554
end	E 11,921,022.711	X 2,438,025.000	dX = 9,482,997.711
East	N 3,527,095.364	Y 246,200.000	dY = 3,280,895.364
end	E 11,951,022.104	X 2,468,025.000	dX = 9,482,997.104

The conversion factor gradient across this sheet is about 0.2 foot in Y and 0.6 foot in X. Such small changes are not significant at the plot scale of 1" = 1,000'; however, for referencing basic design or construction control (either monumented points or within an Intergraph Design File), applying a fixed shift across an area of this size is not recommended -- individual points should be transformed separately. If this 30,000-foot distance were a navigation project, then a fixed conversion factor computed at the center of the sheet would suffice for all bathymetric features.

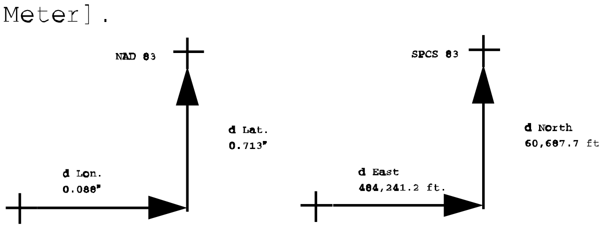
(5) Redefined SPCS 83 grid parameters. In developing the SPCS 83 grid system, some states made significant modifications relative to their previous SPCS 27 grid. As a result, a fixed conversion factor cannot be performed by simply translating the **X** and **Y** differences between SPCS 27 and SPCS 83 -- a grid rotational component may also be present if the central meridian was changed. Variation in the *CORPSCON* computed convergence for both SPCS 27 and 83 is an indication of this. For those states/zones which have been modified, and excessive shift differences occur over small distances, then a fixed conversion factor for even a small area or sheet is not appropriate. A geographic datum shift (in seconds of arc) may still be used in these cases provided the variation over the project/sheet is not significant.

d. Project continuity. Caution should be exercised when converting portions of projects or military installations or projects that are adjacent to other projects that may not be converted. If the same monumented control points are used for several projects or parts of the same project, different datums for the two projects or parts thereof could lead to surveying and mapping errors, misalignment at the junctions, and layout problems during construction.

e. Metric units. SPCS 83 is defined in metric units. Therefore, coordinate conversions between geographic positions (latitude and longitude) and SPCS 83 use metric units. However, since most USACE work will continue in feet, conversion to feet will be required. The FGCC recommended standard for Federal surveying applications in the United States is still the U.S. Survey Foot (1200/3937 Meters). USACE has traditionally used the U.S. Survey Foot and will continue to do so in most instances. However, since some states have adopted the International Foot (30.48/100 meters) and others may choose to use metric units, property and boundary surveys in these states may require this conversion factor, or use of metrics, to be legally correct.

f. Datum notes. During the period of conversion to NAD 83 there will be two datums in use. Therefore, a note must be added to all maps, engineering site drawings, and documents containing coordinate information that indicates which datum is being used. If the control has been converted from NAD 27 to NAD 83, identify the conversion method used. A datum note should be repeated on separate sheets as opposed to a general note on the index or cover sheet. The note will be as follows:

```
The coordinates shown are referenced
to NAD [27/83] and are in feet based
on the SPCS [27/83] [state, zone].
Differences between NAD 27 and NAD
83 and between SPCS 27 and SPCS 83
at the center of the [sheet/data
set] are shown on the diagram below.
Datum conversion was performed using
the computer program "CORPSCON."
Metric conversions were based on [US
Survey Foot = 1200/3937 Meter] or
[International Foot = 30.48/100
Meter].
```



Note: Do not reference SPCS 27-83 differences if the SPCS 83 grid was significantly redefined. In such cases, omit the SPCS 27-83 differences and show only the NAD 27-83 differences in arc seconds of latitude and longitude.

g. Dual grids ticks and coordinate systems. Depicting both NAD 27 and NAD 83 grid ticks and coordinate systems on maps and drawings should be avoided where possible. This is often confusing and can increase the chance for errors during design and construction. However, where use of dual grid ticks and coordinate systems is unavoidable, only secondary grid ticks in the margins will be permitted.

h. Global Positioning System (GPS). GPS surveying techniques and computations are based on WGS 84, which are consistent with NAD 83. Differential (static) GPS surveying techniques are accurate for high order control over very large distances.

(1) Problem. If GPS is used to set new control points referenced to higher order control many miles from the project, inconsistent data may result at the project site. If the new control is near older control points which have been converted to NAD 83, two slightly different networks can result, even though both have NAD 83 coordinates. This slight difference creates problems in adjusting the data and using the two networks as one.

(2) Solution. In order to avoid this situation, locate the GPS base stations on the control in the project area, i.e., don't transfer it in from outside the area. Use the CORPSCON program to convert the old control from NAD 27 to NAD 83 and use these NAD 83 values to initiate the GPS survey. This allows GPS to produce coordinates that are both referenced to NAD 83 and consistent with the old control.

i. Local project datums. Local project datums which are not referenced to NAD 27 cannot be mathematically converted to NAD 83. Field surveys connecting them to other stations that are referenced to NAD 83 are required. GPS is the most economical and accurate technique to accomplish this connection.

4-7. Horizontal Transition Plan

a. General. Not all maps, engineering site drawings, documents, and associated products containing coordinate information will require conversion to NAD 83. To ensure that an orderly and timely transition to NAD 83 is achieved for the appropriate products, the following general guidelines should be followed:

(1) All initial surveys should be referenced to NAD 83.

(2) Active projects where maps, site drawings, or coordinate information are provided to non-USACE users (e.g., NOAA, USCG, FEMA, and others in the public and private sector) should be converted to NAD 83 the next time the project is surveyed or maps or site drawings are updated for other reasons.

(3) For in-active projects or active projects where maps, site drawings, or coordinate information are not normally provided to non-USACE users, conversion to NAD 83 is optional.

(4) Whenever maps, site drawings, or coordinate information (regardless of the above type) are provided to non-USACE users, it should contain a datum note.

b. Levels of effort. For maps and site drawings the conversion process entails one of three levels of effort: conversion of coordinates of all mapped details to NAD 83 and redrawing the map, replace the existing map grid with a NAD 83 grid, and simply adding a datum note. For surveyed points, control stations, alignment, and other coordinated information, conversion must be through either a mathematical transformation or readjustment of survey observations.

c. Detailed instructions.

(1) Initial surveys on civil works projects. The project control should be established on NAD 83 relative to the NGRS using conventional or GPS surveying procedures. The local SPCS 83 grid should be used on all maps and site drawings. All planning and design activities should then be based on the SPCS 83 grid. This includes supplemental site plan mapping, core borings, project design and alignment, construction layout and payment surveys, and applicable boundary or property surveys. All maps and site drawings shall contain datum notes. If the local sponsor requires the use of NAD 27 for continuity with other projects which they have not yet converted to NAD 83, conversion to NAD 27 could be performed using the *CORPSCON* transformation techniques described in Appendix D.

(2) Active civil works O&M projects undergoing maintenance or repair. These projects should be converted to NAD 83 during the next maintenance or repair cycle in the same manner as for newly initiated civil works projects. However, if resources are not available for this level of effort, either redraw the grids or add the necessary datum notes. Plans should be made for the full conversion during a later maintenance or repair cycle when resources can be made available.

(3) Military construction and master planning projects. All MCA, OMA, AFH, OMAR, MCAF, OMAF, and master planning projects will remain on NAD 27 or the current local datum until a thoroughly coordinated effort can be arranged with the MACOM DCSENGR and installation DEH or AFRCE and BCE. An entire installation's control network should be transformed simultaneously to avoid different datums on the same installation. The respective MACOMS are responsible for this decision. However, military operations may require NAD 83, including SPCS 83 or UTM metric grid systems. If so, these shall be performed separate from facility engineering support. A dual grid system may be required for such operational applications when there is overlap with normal facilities engineering functions. Coordinate transformations throughout an installation can be computed using the procedure described in Appendix D. Care must be taken when using transformations from NAD 27 with new control set using GPS methods from points remote from the installation. Installation boundary surveys should adhere to those outlined under real estate surveys listed below.

(4) Real estate.

(a) Surveys, maps, and plats prepared in support of civil works and military real estate activities should conform as much as possible to state requirements. Since most states have adopted NAD 83, most new boundary and property surveys should be based on NAD 83. The local authorities should be contacted before conducting boundary and property surveys to ascertain their policies.

(b) It should be noted that several states have adopted the International Foot for their standard conversion from meters to feet. However, recent action by the FGCS to affirm continued use of the U.S. Survey Foot for Federal surveying activities could lead to a reversal of some state policies.

(c) In order to avoid dual coordinates on USACE survey control points which have multiple uses, all control should be based on the U.S. Survey Foot, including control for boundary and property surveys. In states where the International Foot is the only accepted standard for boundary and property surveys, conversion of these points to NAD 83 should be based on the International Foot, while the control remains based on the U.S. Survey Foot.

(5) Regulatory functions. Surveys, maps, and site drawings prepared in support of regulatory functions should begin to be referenced to NAD 83 unless there is some compelling reason to remain on NAD 27 or locally used datum. Conversion of existing surveys, maps, and

drawings to NAD 83 is not necessary. Existing surveys, maps, and drawings need only have the datum note added before distribution to non-USACE users. The requirements of local, state, and other Federal permitting agencies should be ascertained before site-specific conversions are undertaken. If states require conversions based on the International Foot, the same procedures as described above for real estate surveys should be followed.

(6) Other existing projects. Other existing projects, e.g., structural deformation, beach nourishment, submerged offshore disposal areas, historical preservation projects, etc., need not be converted to NAD 83. However, existing surveys, maps, and drawings should have the datum note added before distribution to non-USACE users.

(7) Work for others. Existing projects for other agencies will remain on NAD 27 or the current local datum until a thoroughly coordinated effort can be arranged with the sponsoring agency. The decision to convert rests with the sponsoring agency. However, existing surveys, maps, and drawings should have the datum note added before distribution to non-USACE users. If sponsoring agencies do not indicate a preference for new projects, NAD 83 should be used. The same procedures as described above for initial surveys on civil works projects should be followed (see paragraph *c*(1)).

4-8. Vertical Datums

A vertical datum is the surface to which elevations or depths are referred to or referenced. There are many vertical datums in the CONUS. The surveyor should be aware of the vertical control datum being used and its practicability to meet project requirements. The following paragraphs will detail further some of the vertical control systems and associated datums used in the CONUS.

a. NGVD 29. NGVD 29 was established by the United States Coast and Geodetic Survey's (USC&GS's) 1929 General Adjustment. NGVD 29 was established by constraining the combined U.S. and Canadian first order leveling nets to conform to MSL as determined at 26 long-term tidal gage stations that were spaced along the east and west coasts of North America and along the Gulf of Mexico, with 21 stations in the U.S. and 5 stations in Canada. The NGVD 29 was originally named the Mean Sea Level Datum of 1929. It was known at the time that because of the variation of ocean currents, prevailing winds, barometric pressures, and other physical causes, the MSL determinations at the tide gages would not define a single equipotential surface. The name of the datum was changed from the Mean Sea Level Datum to the NGVD 29 in 1973 to eliminate the reference to sea level in the title. This was a change in name only; the definition of the datum established in 1929 was not changed. Since NGVD 29 was established, it has become obvious that the geoid based upon local mean tidal observations would change with each measurement cycle. Estimating the geoid based upon the constantly changing tides does not provide the most stable estimate of the shape of the geoid, or the basic shape of the earth.

b. NAVD 88. NGVD 29 has been replaced by NAVD 88, an international datum adopted for use in Canada, the United States, and Mexico. NAVD 88 was established to resolve problems and discrepancies in NGVD 29. The datum for NAVD 88 is based upon the mass or density of the earth instead of the varying heights of the seas. Measurements in the acceleration of gravity are made at observation points in the network, and only one datum point, at Pointe-au-Pere/Rimouski, Québec, Canada, is used. The vertical reference surface is therefore defined by the surface on which the gravity values are equal to the control point value. The result of this adjustment is newly published NAVD 88 elevation values for benchmarks (BMs) in the NGS inventory. Most Third-Order BMs, including those of other Federal, state, and local government agencies, were not included in the NAVD 88 adjustment. The FGCS of the Federal Geographic Data Committee (FGDC) has affirmed that NAVD 88 shall be the official vertical reference datum for the U.S. The FGDC has prescribed that all surveying and mapping activities performed or financed by the Federal Government make every effort to begin an orderly transition to NAVD 88, where practicable and feasible.

c. MSL datums. Some vertical datums are referenced to MSL. Such datums typically are maintained locally or within a specific project area. The theoretical bases for these datums are just as their title indicates: the mean sea level. Local MSL is a vertical datum of reference that is based upon the observations from one or more tidal gaging stations. NGVD 29 was based upon the assumption that local MSL at those 21 tidal stations in the U.S. and 5 tidal stations in Canada equaled 0.0000 foot on NGVD 29. The value of MSL as measured over the Metonic cycle of 19 years shows that this assumption is not entirely valid and that MSL varies from station to station.

d. Tidal datums. Some vertical datums are referenced to tidal waters or lake levels. An example of a lake-level-based tidal datum used as a vertical datum is the International Great Lakes Datum of 1955 (IGLD 55), maintained and used for vertical control in the Great Lakes region of the CONUS. Just like the NGVD, these datums undergo periodic adjustment. For example, the IGLD 55 was adjusted in 1985 to produce IGLD 85. Unlike the prior datum (IGLD 55), IGLD 85 has been directly referenced to NAVD 88 and originates at the same point as NAVD 88. Tidal datums typically are defined by the phase of the tide and usually are described as MHW, MLW, and MLLW with each description having a particular relevance to the datum definition. For further information on these and other tidal-datum-related terms, the reader is advised to refer to any of the applicable texts in Appendix A.

e. Other vertical datums. Other areas of the CONUS and OCONUS may maintain and employ other vertical datums. For instance, there are a variety of vertical datums maintained in Alaska, Puerto Rico, Hawaii, the Virgin Islands, Guam, and other islands and project areas. Specifications and other information for these particular vertical datums can be obtained from the particular FOA responsible for survey-related activities for these areas or the National Ocean Service (i.e., NOS).

4-9. Distinction Between Orthometric and Dynamic Heights

a. There are several different reference elevation systems used by the surveying and mapping community. Two of these height systems are relevant to IGLD 85: orthometric heights and dynamic heights. Geopotential numbers relate these two systems to each other. The geopotential number (C) of a BM is the difference in potential measured from the reference geopotential surface to the equipotential surface passing through the survey mark. In other words, it is the amount of work required to raise a unit mass of 1 kg against gravity through the orthometric height to the mark. Geopotential differences are differences in potential which indicate hydraulic head. The orthometric height of a mark is the distance from the reference surface to the mark, measured along the line perpendicular to every equipotential surface in between. A series of equipotential surfaces can be used to represent the gravity field. One of these surfaces is specified as the reference system from which orthometric heights are measured. These surfaces defined by the gravity field are not parallel surfaces because of the rotation of the earth and gravity anomalies in the gravity field. Two points, therefore, could have the same potential but may have two different orthometric heights. The value of orthometric height at a point depends on all the equipotential surfaces beneath that point.

b. The orthometric height (H) and the geopotential number (C) are related through the following equation:

$$C = G * H$$

where G is the gravity value estimated for a particular system. Height systems are called different names depending on the gravity value (G) selected. When G is computed using the Helmert height reduction formula that is used for NAVD 88, the heights are called Helmert Orthometric Heights. When G is computed using the International Formula for Normal Gravity, the heights are called Normal Orthometric Heights. When G is equal to normal gravity at 45^o latitude, the heights are called Normal Dynamic Heights. It should be noted that dynamic heights are just geopotential numbers scaled by a constant, using normal gravity at 45^o latitude equal to 980.6199 gal. Therefore, dynamic heights are also an estimate of hydraulic head. In other words, two points that have the same geopotential number will have the same dynamic height.

c. IGLD 55 is a normal dynamic height system which used a computed value of gravity based on the International Formula for Normal Gravity. Today, there is sufficient observed gravity data available to estimate “true” geopotential differences instead of “normal” geopotential differences. The “true” geopotential differences, which were used in developing IGLD 85 and NAVD 88, will more accurately estimate hydraulic head.

4-10. Vertical Transformations NGVD 29 to NAVD 88

For map and site plan drawings, including digital variations thereof, the conversion process entails one of two levels of effort: (1) conversion of all elevations to NAVD 88 and redrawing the map, or (2) simply adding a datum note based on an approximate VERTCON conversion.

a. VERTCON is a program developed by the NGS that converts elevation data from NGVD 29 to NAVD 88. VERTCON uses a simplified transformation of BM heights using a modeled shift for a given area and is, in general, only sufficiently accurate to meet small-scale mapping requirements. VERTCON should not be used for converting BM elevations used for site plan design or construction applications. Users can simply input the latitude and longitude for a point and the vertical datum shift between NGVD 29 and NAVD 88 is output. VERTCON returns the orthometric height difference between

NAVD 88 and NGVD 29 at the geodetic position specified by the user. The root-mean-square (RMS) error of the actual NGVD 29/NAVD 88 height differences versus the computed height differences from the model for the data points used to create the model is ±1 cm; the estimated maximum error is ±2.5 cm. Depending on network design and terrain relief, larger differences (e.g., 5 to 50 cm) may occur the further a benchmark is located from the control points used to establish the model coefficients. For this reason, VERTCON should only be used for approximate conversions where these potential errors are not critical.

b. Whenever maps, site drawings, or spatial elevation data are provided to non-USACE users, they should contain a datum note that provides, at minimum, the following information:

> The elevations shown are referenced to the [NGVD 29] [NAVD 88] and are in [feet] [meters]. Differences between NGVD 29 and NAVD 88 at the center of the project sheet/data set are shown on the diagram below. Datum conversion was performed using the [program VERTCON] [direct leveling connections with published NGS benchmarks] [other]. Metric conversions are based on [U.S. Survey Foot = 1200/3937 meters] [International Survey Foot = 30.48/100 meters].

c. There are several compelling reasons that make it advantageous for USACE commands to convert to NAVD 88. These include:

- Differential leveling surveys between benchmarks will often close better.
- NAVD 88 will provide a better reference to estimate GPS-derived orthometric heights.
- IGLD 85 will provide a better reference to estimate heights of water-level surfaces on the Great Lakes.
- Data and adjusted height values will be readily available and accessible in convenient form from NGS's Integrated Data Base.
- Federal surveying and mapping agencies will stop publishing on NGVD 29 and IGLD 55, and will publish only on NAVD 88 and IGLD 85.
- Surveys performed for the Federal government will require use of NAVD 88.
- NAVD 88 is recommended by ACSM and FGCS.

4-11. Vertical Transition Plan

A change in vertical datum will affect most USACE engineering, construction, planning, and surveying activities. The cost of conversion could be substantial at the onset. There is a potential for errors in conversions inadvertently occurring. The effects of the vertical datum change can be minimized if the change is gradually applied over time; being applied to future projects and efforts, rather than concentrated on changing already published products. In order to ensure an orderly and timely transition to NAVD 88 is achieved for the appropriate products, the following general guidelines in this section should be followed.

a. Conversion criteria. Maps, engineering site drawings, documents, and associated spatial data products containing elevation data may require conversion to NAVD 88. Specific requirements for conversion will, in large part, be based on local usage -- that of the local sponsor, installation, etc. Where applicable and appropriate, this conversion should be recommended to local interests.

b. Newly authorized construction projects. Generally, initial surveys of newly authorized projects should be referenced to NAVD 88. In addition to design/construction, this would include wide-area master plan mapping work. The project control should be referenced to NAVD 88 using conventional or GPS surveying techniques. All planning and design activities should be based upon NAVD 88. All maps and site drawings shall contain datum notes as described below. If the sponsor/installation requires the use of NGVD 29 or some other local vertical reference datum for continuity, the relationship between NGVD 29 and NAVD 88 shall be clearly noted on all maps, engineering site drawings, documents, and associated products.

c. Active projects. On active projects where maps, site drawings, or elevation data are provided to non-USACE users, the conversion to NAVD 88 should be performed. This conversion to NAVD 88 may be performed the next time the project is surveyed or when the maps/site drawings are updated for other reasons. Civil works projects may be converted to NAVD 88 during the next maintenance or repair cycle in the same manner as that for newly initiated civil works projects. However, if resources are not available for this level of effort, either redraw the maps or drawings and add the necessary datum note. Plans should be made for the full conversion during a later maintenance or repair cycle when resources can be made available. MCA, OMA, AFH, OMAR, MCAF, OMAF and master planning projects should remain on NGVD 29 or the local vertical datum until a thoroughly coordinated effort can be arranged with the MACOM DCSENGR and installation DEH, or AFRCE and BCE. An entire installation's control network should be transformed simultaneously to avoid different datums on the same installation. MACOMs should be encouraged to convert to NAVD 88. However, the respective MACOMs are responsible for this decision.

d. Inactive projects. For inactive projects or active projects where maps, site drawings, or elevation data are not normally provided to non-USACE users, conversion to NAVD 88 is optional.

e. Work for others. Projects for other agencies will remain on NGVD 29 or the current local vertical datum until a thoroughly coordinated effort can be arranged with the sponsoring agency. Other agencies should be encouraged to convert their projects to NAVD 88, although the decision to convert rests with the sponsoring agency. However, surveys, maps, and drawings should have a datum note added before distribution to non-USACE users. If sponsoring agencies do not indicate a preference for new projects, NAVD 88 should be used.

f. Miscellaneous projects. Other projects referenced to strictly local datum, such as structural deformation, beach nourishment, submerged offshore disposal areas, historical preservation projects, etc., need not necessarily be converted to NAVD 88. However, it is recommended that surveys, maps, and drawings have a clear datum reference note added before distribution to non-USACE users.

g. Real estate implications.

(1) Surveys, maps, and plats prepared in support of civil works and military real estate activities should conform as much as possible to state requirements. Many states are expected to adopt NAVD 88 (by statute) as an official vertical reference datum. This likewise will entail a transition to NAVD 88 in those states. State and local authorities should therefore be contacted to ascertain their current policies.

(2) Note that several states have adopted the International Foot for their standard conversion from meters to feet. However, recent action by the FGCS to affirm continued use of the U.S. Survey Foot for Federal surveying activities could lead to a reversal of some state policies.

(3) In order to avoid dual elevations on USACE survey control points which have multiple uses, it is recommended that published elevations be based on the U.S. Survey Foot. In states where the International Foot is the only accepted standard for boundary and property surveys, conversion of these elevations to NAVD 88 should be based on the International Foot while the control remains based on the U.S. Survey Foot.